Regional correlations suggest that the Bradford-Balltown and Speechly (B sands of Pennsylvania Geological Survey) sands are better developed in northwestern Pennsylvania, whereas the Bayard through Gantz (D sands of Pennsylvania Geological Survey) sands are better developed in northern and central West Virginia, decreasing also in buildup toward southeastern West Virginia. The oil-bearing sandstones occur in strike trend (north-south) in north-central West Virginia connected by feeder channel sandstones with dip trends (east-west). The interpreted fluvial and tidal channels combine to represent distributary channels that supplied the sands to the barrier islands and delta front. Shoreline shifts, with regression and transgression of the ancient sea, caused corresponding changes in distal-fan accumulations with time.

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Upper Devonian Deposystems of Catskill Delta, West Virginia

The oil and gas reservoir rocks of the Upper Devonian of West Virginia were deposited as shoreline sands along a coastal plain characterized by marine-dominant deltas (Catskill delta complex). The oil-bearing sandstones occur in strike trend (north-south) in north-central West Virginia connected by feeder channel sandstones with dip trends (east-west). In outcrop, the strike-trending sandstones contain occasional marine fossils, are well sorted, and exhibit sedimentary structures that suggest depositional environments ranging from shoreface to tidal delta and back barrier. Channel sandstones with herringbone bedding suggest tidal influence. These beds change to cross-bedding of unidirectional paleoflow origin in upstream fluvial counterparts of red-bed facies. The interpreted fluvial and tidal channels combine to represent distributary channels that supplied the sands to the barrier islands and delta front. Isolith maps show anastomosing belts trending east-west with both vertical and offset stacking. Stream avulsion and stream piracy probably account for lateral shifting of tidally influenced river distributaries. Gridlike patterns of sandstone belts result from the dynamic interference of tidal-fluvial channels with wave-constructed shoreline barrier islands and bars, complicated by onlap and offlap cycles. Subsurface informally named oil and gas sands generally are multiple sandstones. Detailed correlation of individual sand units is difficult, but it supports the interpretation of a combined influence of wave and tidal-fluvial processes.

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Depositional Facies and Diagenetic History of Trenton Limestone in Northern Indiana

Subsurface cores were studied petrographically to determine the facies and diagenetic history of the Trenton Limestone on a regional scale in northern Indiana.

The Trenton Limestone is a yellowish olive-gray fossiliferous limestone, which is replaced by a light-gray dolostone in northern Indiana. Facies composing the Trenton are: (1) bryozoan-echinoderm packstone, (2) bryozoan-echinoderm grainstone, (3) bryozoan packstone to wackestone, (4) lime mudstone, and (5) dolostone. The bryozoan-echinoderm packstone is the major facies. As many as three muddying-upward (packstone to mudstone) sequences occur. Whether the muddying-upward sequences represent regional or local energy conditions is not known. Coarse-grained (1-4 mm) grainstones are typically 1 ft (30 cm) thick, have abrupt bases, and become muddy upward. They are considered storm deposits. Hardgrounds occur throughout the limestone facies, but they are most numerous toward the base. These facies indicate deposition below wave base, interrupted by periods of high energy during storms. Fossiliferous white and gray chert nodules are scattered throughout the unit. Also found in the limestone facies are prevalent stylolites and microstylolites, an indication of chemical compaction.

The dolostone facies consists of coarsely crystalline (0.4 mm) idiotopic dolomite. Rhombs have cloudy centers and thin clear rims. Pyrite is associated with the dolomite. Porosity, found only in the dolostone, is discontinuous and characterized as intercrystalline, vuggy, and moldic. Porous zones are commonly oil stained or have been plugged by poikilotopic selenitic gypsum. Minor amounts of celestite are found as cavity fillings.

The upper Trenton surface has high concentrations of pyrite and phosphate minerals and is interpreted to have been a submarine corrasion surface.

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Cyclic Sedimentation Patterns in Middle Ordovician Trenton Group in Central Pennsylvania

The carbonate facies of the Middle Ordovician Trenton Group show repetitive sequences of micrite, bioclastic limestone, and siliciclastic shale. Five repetitive patterns based on sedimentologic and paleontologic data are present (in ascending order): (1) biosparite, (2) intrabiosparite, (3) pelsparite, (4) micrite, (5) alternating micrite and shale.

The biosparite is of peritidal origin and is overlain by a stromatolitic cap. The average sequence thickness is 30-40 cm (12-16 in.). The intrabiosparite is a fining-upward sequence that grades to pelsparite with a micrite cap (total thickness averages 16 cm or 6 in.). This sequence is indicative of intershoal or shoaling conditions. Overlying the intrabiosparite sequence is pelsparite grading into a micrite cap. The pelsparite averages 8 cm (3 in.) in thickness, and is of shallow sublittoral origin. Highly burrowed micrite (2-6 cm or 0.8-2.4 in. thick), with a hardground cap, indicates periodic exposure. The upper unit is a deeper, sublittoral sequence of alternating kerogenic micrite and siliciclastic shale, ranging in thickness from 20 to 90 cm (7.9 to 35.4 in.). This pattern indicates a deepening of the carbonate shelf into a deeper, anoxic basin below wave base.

These sequences are a result of storm deposition as indicated by shell and intraclast lags, by fining-upward trends, and by abrupt contacts between individual sequences. The series of sequences is a result of the decreasing effects of these storms in the deeper water facies.

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To Drill or Not to Drill: a Synthesis of Experts' Judgments

Petroleum exploration is a costly venture that always involves much uncertainty and many unknown factors. A decision to drill could result in a giant discovery, a modest discovery, or a dry hole.

Using experts' judgments and the available information on a geologic formation, we estimate the volume of recoverable oil in a given reservoir by a method called the analytic hierarchy process (AHP).

AHP is a mathematically based modeling tool that allows an analyst to derive priorities for a set of alternatives by simple pairwise comparisons. The setting of priorities involves the solution of an eigenvalue problem in the inverse matrix of pairwise comparisons. The factors are grouped on different levels, forming a chain or hierarchy, whereby the lower level elements can be compared in pairwise matrices with respect to the next level. A process of weighting yields the overall priorities for any level, but in particular for those in the lowest level.

The factors affecting the decision are assigned numerical values using judgments of geologists and petroleum engineers. The probabilities of the outcomes are determined and the "expected value" of each decision is computed. The results of the study indicate that, when good judgments are used, one can obtain an excellent estimate of the volume of recoverable oil in a reservoir in a very short time and with the least amount of physical and financial resources.

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Deposition in Anoxic Taconic Foreland Basin, Late Middle Ordovician, New York

The Taconic foreland basin resulted from a collision between the North American craton and the Ammonoosuc arc. The basin is positioned between a broad carbonate shelf on the west and the clastic arc terrane. In the downslope direction, basin deposits changed from distal shelf carbonates (Trenton Limestone), to coeval interbedded hemipelagic black shales and calcilutites on the slope (Dolgeville Formation and Utica Shale), to silty shales, siltstones, and sandstones laid down by turbidites on the basin floor (Snake Hill Shale). Transport direction was to the east on the slope, and axial (north-northeast–south-southwest) on the basin floor. Clay particles were derived from the volcanic source terrane. The facies gradually shifted west laterally; the length of time span investigated is about 6 m.y.

From the distribution of organic carbon and the concentration of benthic epifauna and infauna, it can be inferred that conditions were aerobic on the shelf (> 1 ml/L O_2), anaerobic on the slope (< 0.4 ml/L O_2), and dysaerobic on the basin floor (< 1 ml/L O_2). Through time, four long-term anaerobic and dysaerobic cycles are revealed, lasting between 500,000 and 1,000,000 yr. Anaerobic cycles are characterized by over 50% higher organic carbon values, lack of infaunal burrowing traces, and a highly impoverished benthic epifauna. Dysaerobic cycles are marked by lower organic carbon contents, sporadic burrowing traces, and a slightly more diverse and abundant benthic epifauna. This cyclicity was most likely caused by changes in the density stratification within the water column, possibly related to climatic changes. The longest anaerobic cycle occurred during the transgressive phase that led to widespread deposition of black shale over the carbonate platform.

Anoxic conditions in the Taconic foreland basin may have been influenced by the prevailing global oceanographic conditions during the Middle Ordovician.

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Subsurface Stratigraphy of Upper Cambrian Through Carboniferous Rocks in Western and Central Pennsylvania

The analysis of geophysical well log data from 20 deep wells in western and central Pennsylvania, southern New York, and northern West Virginia confirms the presence of anomalies in the distribution and thickness of the Lower Ordovician Beekmantown, Middle Ordovician Trenton, Lower Devonian Oriskany, and Middle Devonian Onondaga and Tully rock units. The nonuniformity of these rock units occurs in an area of western Pennsylvania referred to by W. R. Wagner in 1976 as the Olin basin. The margins of this feature are delineated by Upper Cambrian and Lower Ordovician growth faults. Wagner considered these faults to be extensions of Precambrian basement faults.

A structural depression in southwestern Pennsylvania and northwestern West Virginia hosted the depocenters of many of the Ordovician, Silurian, and Devonian sediments. This feature coincides geographically with the southern boundaries of the Late Cambrian Olin basin. Displacement along Precambrian basement faults coincident with this structure could have accounted for the distribution and thickness of the Beekmantown sediments in this region. The correlation of bentonite layers of the Trenton Group in western Pennsylvania indicates that faulting coincident with this depression appears to have affected the distribution and thickening of sediments across this basin.

Limited, renewed displacement of Wagner's Upper Cambrian growth fault as a positive flexure, resulting in an uplift of basement highs in Devonian time, might have accounted for the minimum deposition of the Oriskany, Onondaga, and Tully units in western and north-central Pennsylvania.

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Effects of Clastic Dikes on Roof-Rock Stability in Central Pennsylvania Coal Mine

Clastic dikes are common in coal beds of the Appalachian basin. Their presence often causes delays in mine production and poses safety hazards to mine personnel. The U.S. Bureau of Mines is conducting research on the occurrence and origin of clastic dikes and associated roof-rock instability, to gain a better understanding of the effect clastic dikes have on ground pressure around mine openings. Geologic mapping and pressure monitoring of clastic dikes at the Greenwich Collieries North Mine, Indiana County, Pennsylvania, has provided insights to this problem.

The North Mine (producing from the lower Freeport coal bed) is experiencing an increase in the number of clastic dikes and associated roof failure as mining advances toward the axis of the Brush Valley syncline. Over 200 individual clastic dikes of claystone matrix with fragments of shale and coal have been mapped at the mine. The dikes range in thickness from a maximum of 2 ft (60 cm) to as small as 0.25 in. (6 mm) and commonly extend vertically from the roof rock 20 ft (6 m) above the coal bed into the coal bed, but rarely through the coal bed to the underclay. Observations of the dikes indicate that they were formed by tensional and compressional forces and may be related to paleostress fields. Characteristically the dikes penetrate the coal bed at high angles to bedding with as much as 8 in. (20 cm^3) of normal-fault type displacement at the contact of coal bed and roof rock. The measured strike of the clastic dikes shows a strong bimodal distribution of N40°W and N50°E, which is offset 30° to the east of the bimodal distribution of the coal cleat (face N70°W and butt N20°E). Joints in the shale roof rock show a dominant peak of N 40° W, which is coincident with one of the major peaks of the dike distribution.

The depositional environment may have been an important factor in clastic dike formation, as the abundance of preserved casts of tree stumps in the shale roof is inversely proportional to the number of clastic dikes.

Hydraulic pressure-monitoring devices were installed near the clastic dikes to monitor the development of associated roof failure. The results of this monitoring show that the roof behaved as two cantilever beams where a clastic dike was present and that the roof must be supported immediately after mining. Analysis of the anisotropic qualities of the roof strata and rock-pressure conditions suggests that changes in the in-situ stress field near clastic dikes have aided in the propagation of roof failure.

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Berea Sandstone Reservoirs in Ashland and Medina Counties, Ohio

The Berea Sandstone is one of the better known rock formations in Ohio. It occurs at shallow depths throughout a broad belt in central Ohio and crops out to the north and west of these counties. Stratigraphically, the Berea Sandstone is part of the Waverly Group and is underlain by the red and gray Bedford Shale and overlain by the black Sunbury Shale, all of which are of Early Mississippian age.

In Ashland and Medina Counties, the Berea may be divided into two separately identifiable units. The upper unit, called the "blanket" Berea in outcrop, is approximately equivalent to the "cap" Berea in the subsurface. The second unit, which lies below the "cap" Berea varies considerably in its thickness. The thickness of the Berea Sandstone (excluding the "cap") ranges from zero to over 125 ft (38 m) in the study area. The thickness changes occur within very short distances (i.e., 100-200 ft or 30-60 m) owing to the original depositional conditions responsible for the formation of the sand body.

The traditional, long-standing, and generally accepted view is that the Berea Sandstone was deposited in Ashland and Medina Counties in southward-flowing river channels. More recent drilling in these counties has demonstrated that these sand channels are not continuous, but are isolated sandstone bodies in which petroleum has accumulated.

The reservoir capacity of the Berea is between 8 and 22% with an average porosity of 15%. The sandstone consists of loosely cemented, medium to fine-grained quartz with only rare shale breaks below the "cap" Berea. In Ashland and Medina Counties, Berea wells generally produce oil. Initial production in this area ranges between 1 or 2 bbl and to 40 BOPD after treatment. Reservoirs in the Berea Sandstone generally are productive where the sandstones are thick. They are also productive where the sandstone is thinner, but high on structure. Although a high structural position is preferred, the critical consideration is the thickness of the sandstone body and the reservoir geometry.

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Coal Rank Trends in Eastern Kentucky

Examination of coal rank (by vitrinite maximum reflectance) for eastern Kentucky coals has revealed several regional trends. Coal rank varies from high volatile C (0.5% R_{max}) to medium volatile bituminous (1.1% R_{max}), and generally increases to the southeast. One east-west–trending rank high and at least four north-south–trending rank highs interrupt the regional increase. The east-west–trending rank high is associated with the Kentucky River faults in northeastern Kentucky. It is the only rank high clearly associated with a fault zone. The four north-south–trending rank